Isolation of Hydrogen from Water by Sonophotocatalysis Using Alternating Irradiation Method

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1. Introduction

Many methods for hydrogen production have been proposed. It is thought that the most attractive hydrogen source is water. Photocatalytic decomposition of water is very attractive from the viewpoint of solar energy conversion. In recent paper, it has found that pure water is decomposed to H_2 and O_2 by the simultaneous irradiation of light and ultrasound in the presence of TiO_2 [1]. Although TiO_2 is often used as a photocatalyst, it is difficult to perform the reaction using visible light because of large band gap. In order to use visible light, several kinds of powdered photocatalysts were examined. In the case of $BiVO_4$, H_2 and O_2 were evolved from pure water continuously. Thus, this material is a candidate for an O_2 evolution photocatalyst to construct the two-step sonophotocatalytic reaction system.[2]

Meantime, evolved H_2 from this system was mixed with O_2 although it was hopeful to isolate H_2 from products. In the case of electrolysis, which is a typical process for decomposition of water, H_2 and O_2 are obtained independently on the cathode and anode, respectively.

In this prasantation, the possibility of product isolation for the sonophotocatalysis of water using visible light and ultrasound was examined.

2. Experimental

As the powdered photocatalysts, $BiVO_4$, TiO_2 and etc. were used. The sample of $BiVO_4$ was synthesized by aqueous processes[3]. Other photocatalysts were supplied by manufactures. Light and ultrasound were irradiated from one side with a 500-W Xenon lamp and from the bottom surface with a 200-W ultrasonic generator (200 kHz.), respectively. The irradiation of visible light was performed with a shorter wavelength cut off filter. The amounts of gaseous reaction products were analyzed by gas chromatography.

3. Results and discussion

In the sonophotocatalysis, it was thought that water was decomposed to H_2 and O_2 by two-step reaction as follows [1];

1st step: Sonochemical process,

$$2H2O \rightarrow H2 + H2O2 \cdots (1)$$

2nd step: Heterogeneous photocatalytic process,

$$2H2O2 \rightarrow O2 + 2H2O \cdots (2)$$

If the two-step mechanism (1) and (2) is valid, each product will be produced independently by alternating irradiation using by ultrasound and light. Sonophotocatalysis of water was performed under argon atmosphere by an alternating irradiation method; sonolysis of water, followed by photocatalysis. This order of irradiation was decided from the scheme of sonophotocatalysis of water. As the result, H_2 and O_2 were collected independently using not only TiO_2 but also $BiVO_4$ photocatalyst under white light irradiation of Xe-lamp.

In the case of electrolysis of water, each gaseous product is evolved on the different place(electrode) at the same time. On the other hand, in the case of sonophotocatalysis, each product was evolved in the same place (reactor) at the different time.

When the sharp cut filter of Y-43(Transmittance was 0.5 at 430nm and edge of absorption was 400nm) was inserted to the light path, BiVO4 photocatalyst retained the reactivity although O2 production rate decreased vigorously for TiO2 photocatalyst. When shorter wavelength cutting filter of O-53(Transmittance was 0.5 at 530nm and edge of absorption was 500nm) was inserted to the light path, reaction rate decreased vigorously because the band gap of BiVO4 was 2.4eV, which corresponded to 510nm.

As conclusion, H_2 and O_2 were collected independently from water by the alternating irradiations of ultrasound and visible light using the visible light-sensitive photocatalyst.

References

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[3] A.Kudo, K.Omori, and H.Kato, *JACS*, **121**, 11459 (1999).